Investigation of a Jet Pump-Based Two-Phase Thermal Control System

Jon B. Holladay/ED62
205–544–7250
E-mail: jon.holladay@msfc.nasa.gov

Melissa Y. Gard/ED62
205–544–4337
E-mail: melissa.gard@msfc.nasa.gov

Patrick L. Hunt/ED63
205–544–2297
E-mail: patrick.hunt@msfc.nasa.gov

A two-phase thermal cooling (TCS) system that has been under study recently (fig. 65) for use in aerospace (or commercial) applications incorporates a jet pump. This system offers several advantages over conventional two-phase pumped loops. Its most significant advantage is that electrical power is only needed to initiate the flow of coolant in the loop. Once flow is initiated, the waste heat is used to drive the flow around the loop.

The primary purpose of this Center Director's Discretionary Fund (CDDF) project is to investigate jet pump-based two-phase heat rejection systems. This investigation will demonstrate whether this type of system is practical for use in aerospace applications.

In order to investigate and quantify the performance attainable by a jet pumped system, design, fabrication and testing of a two-phase heat rejection flow loop apparatus is proposed (fig. 65). This apparatus will initially be used to verify previous research[1] and then modified to gain practical experience as well as design data for related hardware.

Over the last year a significant amount of research has been completed. The initial thrust of the project included gathering technical information on jet pumps and their applications. Over 100 articles were reviewed and a data base generated for reference purposes.

Three analytical methods were selected for simulating the jet pump. This approach provides many benefits including:

- Timely data required for design;
- Backup if the other methods stall;
- Analytical verification (independent analyses); and
- A better understanding of the physics of the flow than provided in previous papers.

The three analytical methods chosen were:

- Homogeneous equilibrium model (HEM): This model is based on the previously referenced Russian-sponsored work done by Fairuzov.[1] The model uses one-dimensional, two-phase flow initially assuming isentropic-homogeneous expansion with corrections for friction loss using velocity coefficients. This model can be easily integrated into a flow loop model for the iterative procedure necessary to solve the set of equations that characterize the overall two-phase system.
- Two-dimensional axisymetric computational fluid dynamic (CFD) models, fluid dynamic analyses package (FIDAP). The CFD model provides the capability to perform detailed performance evaluations of the pump including parametrics in two dimensions. It also allows the flow characteristics to be evaluated visually. Compressibility as well as two-phase mixing is included in the model. Several user adjustments had to be made in order to accurately simulate the flow due to the diffuser shock wave.
- One-dimensional compressible flow mixing model (CoFlo). One of the project goals is to develop a generalized formulation for jet pump compression ratio as well as the jet pump efficiency in terms of relevant flow and heat transfer parameters and examine the conditions under which both quantities can be maximized. This model splits the pump into several sections (primary nozzle, mixing throat, mixing tube, diffuser upstream, shock layer, downstream diffuser) employing appropriate solution techniques for each region to determine the pump "performance." This model will also have the capability for interface with the facility models to simulate the full-up system configuration.

If the results of the jet pump experiments prove promising, continued research including additional ground-based testing, proposed on-orbit testing, and additional analytical modeling is planned. Research from this study already appears to have potential for significant contributions to the area of two-phase jet pump research.

[1]Fairuzov, Y. Y.; and Bredikhin, V. V.: "Two-Phase Cooling System With a Jet Pump for Spacecraft." *Journal of Thermophysics and Heat Transfer*, vol. 9, no. 2, 1995.

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Biographical Sketch: Jon Holladay, Patrick Hunt, and Melissa Gard are members of MSFC's Thermal and Life Support Division team. They have over 30 years of experience in the thermal fluids area. Jon Holladay has bachelor and master of science degrees in mechanical engineering from the University of Alabama. Hunt earned bachelor and master's degrees in mechanical engineering from Auburn University, and Gard has a bachelor of science degree in engineering physics from Southwestern Oklahoma State University.

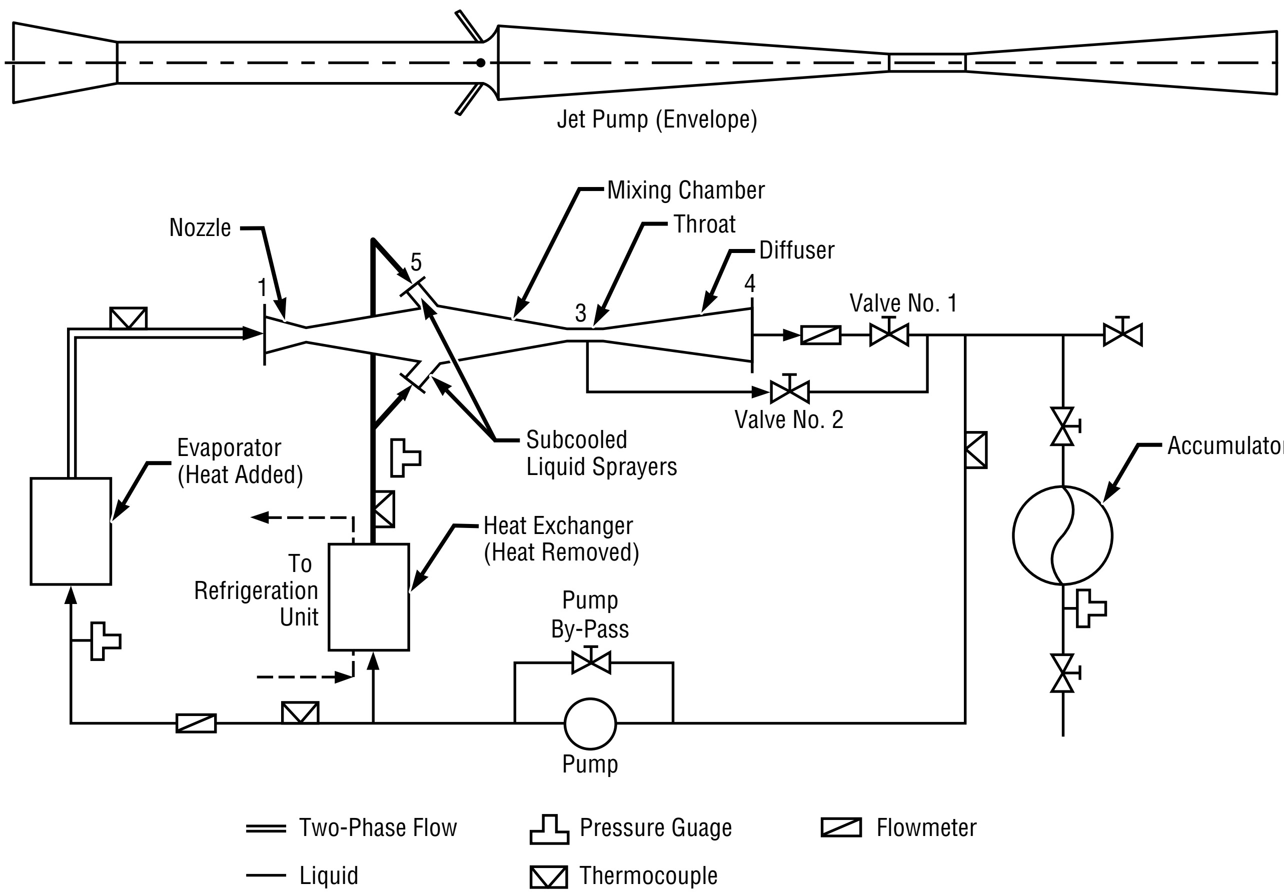

Figure 65.—Two-phase jet-pumped flow loop apparatus.